EPA U.S. Environmental Protection Agency Washington, DC
EPA-SAB-EPEC-91-001

Report of The Ecological Monitoring Subcommittee of The Ecological Processes and Effects Committee

Evaluation of The Ecological Indicators Report for EMAP

A SCIENCE ADVISORY BOARD REPORT November 1990

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
THE ADMINISTRATOR

November 6, 1990

EPA-SAB-EPEC-91-001

The Honorable William Reilly
Administrator
U.S. Environmental Protection Agency
401 M. Street, S.W.
Washington, D.C. 20460

Dear Mr. Reilly:

The Ecological Monitoring Subcommittee of the Science Advisory Board (SAB) has completed its review of the interim conceptual plan entitled "Ecological Indicator Report for the Environmental Monitoring and Assessment Program (EMAP)". As you are aware, the Science Advisory Board recommended that a program be implemented within EPA to monitor the status, extent, and geographic distribution of our ecological resources and assess changes in the condition of those resources on a regional and national scale. The selection of indicators is a critical step in the program because indicators will define the condition of ecosystems.

We are pleased that the Office of Research and Development (ORD) is developing EMAP to address this need, and we look forward to future reviews of its principal components and strategies. We believe, in concert with ORD, that the SAB reviews will complement the focused Peer Reviews for particular ecosystems and the long-term assessment that is proposed for the National Research Council.

The Subcommittee met on May 8-9, 1990, to review and evaluate the Indicator report. ORD asked the Subcommittee to address the following questions as part of their review:

a. Are the concepts of the indicators clearly articulated?
b. Are the data in the appendices on individual indicators relevant and accurate?
c. Is the suite of indicators sufficient and appropriate for each ecosystem? Will the results of such monitoring

be relevant given the temporal and spatial scale of the program?

d. Is the current classification of ecosystems appropriate?

The Subcommittee supports the EMAP concept and commends the program for the careful and iterative approach that has been taken to selecting indicators. While this promotes extensive reviews it has also led to a proliferation of terminology and a divergence in the concept of indicators that are applied among different ecosystems. We recommend that the revised report contain a glossary and an explicit rationale for the selection of the indicators, and clarifications of the term habitat indicators.

The use of data in the text and appendices is quite uneven for different parts of the report. In addition to our ecosystem specific comments, we recommend that the report include a matrix of selection criteria for each ecosystem strategy. The sufficiency of the indicators and the stage of development and testing varies significantly among ecosystems. We have provided specific comments and encourage the program to accelerate the schedule for research on risk characterization. ORD must clarify the use of the terms "nominal" and "subnominal". This incorrectly implies that the indicators will identify a cause. The relevance of the results should be evaluated after each demonstration pilot; pilot monitoring studies and other techniques for midcourse corrections are essential due to the temporal scale of EMAP and its reliance on many Agencies.

The current ecosystem classification system is in some cases artificial (e.g., agro-ecosystems that include fish farms and wheat fields) and in some cases illogical (e.g., wetlands have little in common that range from tundra to mangrove swamps). But most importantly it may inhibit a focus on the integration of regional environmental factors and the pooling of monitoring resources that an assessment of ecological functions needs. We recommend that EMAP consider a pilot to test the use of biogeographic regions as assessment units as a possible alternative to ecosystem classes.

Although we expect the Program Office will address all of the issues presented in this report, we respectfully direct your attention to these:

-the need to integrate and use historical data

-the implication that EMAP will identify causality

-the artificial nature of the current ecosystem classification and the plans to evaluate the use of ecoregions as assessment units

-the rationale for selection of indicators

-the plans to evaluate results of pilot studies

-the inconsistent use of terms such as nominal and subnominal.

The SAB appreciates the opportunity to conduct this scientific review and looks forward to receiving your response to the scientific advice transmitted herein.

Sincerely,

Raymond C. Loehr

Dr. Raymond Loehr, Chairman
Executive Committee
Science Advisory Board

Kenneth L. Dickson

Dr. Kenneth Dickson, Chairman
Ecological Processes and
Effects Committee

ABSTRACT

This report presents the conclusions and recommendations of the U.S. Environmental Protection Agency's Science Advisory Board following a review of the draft document "Ecological Indicator Report for the Environmental Monitoring and Assessment Program" (EMAP). EMAP, the Agency's program to monitor the status and trends of regional and national ecological resources, will evaluate and use indicators to measure and describe the overall condition of ecosystems. Specific sets of indicators which quantify response to anthropogenic stress (response indicators), exposure to pollutants or causes of poor condition (exposure indicators), and measure human activities which are suggestive of environmental stress (stressor indicators) are being evaluated for each class of ecosystem. This approach is evolving and the Subcommittee considered that EMAP had made good progress through its peer reviews of the overall approach and the interim plan for indicators. The development of indicators was in different stages for each of the ecosystems; however the use of a field demonstration pilot is a good technique which could promote interactions between the ecosystem scientists. The terminology for defining "nominal", "subnominal", and habitat indicator should be clarified and selection of indicators by all ecosystem classes should be better coordinated and integrated with ecological risk assessment principles. The EMAP team should rely on historical data, where possible, to estimate sampling requirements and assess trends and they should reassess their ability to identify causal relationships through this regional scale of monitoring. Other comments and suggestions for clarification are provided in the report.

Key Words: Indicators; Environmental Quality; Monitoring; Stress.

U.S. ENVIRONMENTAL PROTECTION AGENCY
NOTICE

This report has been written as a part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide a balanced expert assessment of scientific matters related to problems facing the agency. This report has not been reviewed for approval by the Agency; and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency or other agencies in Federal Government. Mention of trade names or commercial products does not constitute a recommendation for use.

U.S. ENVIRONMENTAL PROTECTION AGENCY
SCIENCE ADVISORY BOARD
ECOLOGICAL PROCESSES AND EFFECTS COMMITTEE
ECOLOGICAL MONITORING SUBCOMMITTEE
ROSTER

CHAIRMAN

Dr. Kenneth Dickson
Director
University of North Texas
Institute of Applied Sciences
P.O. Box 13078
Denton, Texas 76203

VICE-CHAIRMAN

Dr. Stanley Auerbach
Director
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

MEMBERS

Dr. Yoram Cohen
Associate Professor
Engineering Department
UCLA Rm. 5531
Boelter Hall
Los Angeles, California 90024

Daniel Goodman
Montana State University
Department of Biology
Louis Hall
Bozeman, Montana 59717

Dr. Rolf Hartung
Professor
School of Public Health
3125 Fernwood Avenue
University of Michigan
Ann Arbor, Michigan 48108-1955

Dr. Allan Hirsch
Director, Washington Operations
Midwest Research Institute
Falls Church, Virginia 22041

Dr. Kenneth Jenkins
Director
Molecular Ecology Institute
California State University
Long Beach, California 90840

Dr. Richard Kimerle
Monsanto Corporation
800 N. Lindbergh Boulevard
St. Louis, Missouri 63167-5842

Dr. Richard F. Lee
Skidaway Institute of Oceanography
P.O. Box 13687
Savannah, Georgia 31416

Dr. John Neuhold
Department of Wildlife Sciences
College of Natural Resources
Utah State University
Logan, Utah 84322

Dr. William H. Smith
Professor of Forest Biology
School of Forestry
and Environmental Studies
Yale University
370 Prospect Street
New Haven, Connecticut 06511

Dr. Leonard H. Weinstein
Boyce Thompson Institute Plant Res
at Cornell
Tower Road
Ithaca, New York 14853

SCIENCE ADVISORY STAFF

Dr. Edward S. Bender
Biologist & Executive Secretary
U.S. Environmental Protection Agency
Science Advisory Board
401 M Street, SW.
Washington, D.C. 20460

Ms. Frances A. Dolby
Secretary to the Executive Secretary

TABLE OF CONTENTS

1.0 Executive Summary. 1

2.0 Introduction 2

2.1 Charge to the Subcommittee 3

3.0 Evaluation of the Indicator Report 4

3.1 General Comments 4

3.1.1 The EMAP Concept 4
3.1.2 EMAP Strategy. 5
3.1.3 Inter-agency Coordination. 5
3.1.4 Peer Review. 6
3.1.5 Discussion of the Charge 6
3.1.6 Assessment Systems 7
3.1.7 Habitat Indicators 8
3.1.8 Sampling Strategy. 8
3.1.9 Historical Data. 9
3.1.10 Model Ecosystem Approach. 10
3.1.11 Coordination and Integration. 10
3.1.12 Biogeographic Regions 11
3.1.13 Cost Estimates. 12

3.2 Recommendations for Revising the Indicator Report. . 13

3.2.1 Cross-cutting Indicators 13
3.2.2 Wetlands 14
3.2.3 Near-Coastal Waters 15
3.2.4 Forests. 17
3.2.5 Arid Lands 18
3.2.6 Agro-Ecosystems. 18

3.3 Testing Indicators 19

3.3.1 Document Rationale 19
3.3.2 Resource Types 19
3.3.3 Consistency of Terms 20
3.3.4 Indicator Selection Criteria 20
3.3.5 Causation Versus Correlation 20
3.3.6 Indicator Development Process. 20
3.3.7 Indicator Research 21
3.3.8 Summary Chapter. 21

4.0 Summary of Recommendations 21

1.0 EXECUTIVE SUMMARY

The Environmental Monitoring Subcommittee of the Ecological Processes and Effects Committee of the Science Advisory Board met on May 8-9, 1990, to review the draft document "Ecological Indicator Report for the Environmental Monitoring and Assessment Program" (EMAP).

The Subcommittee recognizes the inherent difficulties involved in identifying EMAP indicators and appreciates the substantial effort and progress reflected in the report. We recognize that this report is being developed as an interim document to summarize work to date in developing EMAP indicators and to elicit further comment and we reviewed the document from that standpoint. We have identified a number of conceptual and substantive issues that require further clarification and resolution. Our Subcommittee's comments and recommendations address both fundamental questions with respect to selection of indicators, and questions relating to improvement and clarification of the way in which such information was presented in the report.

The Subcommittee also commented on broader aspects of the EMAP conceptual design and sampling strategy which we consider inextricably linked to selection of appropriate indicators. We reiterate support for the EMAP concept, and commend the EMAP team for its efforts toward inter-agency coordination and peer review. We further stress the importance of testing EMAP concepts through conduct of pilot studies and for carefully evaluating results of those studies before proceeding with full scale implementation.

Among our more salient findings and recommendations are:

1. Clarification is required on the concept of assessing ecosystems as "nominal" or "subnominal"; this concept has not been clearly developed.

2. Clarification is required on the definition of "habitat" indicators. There is ambiguity in the way the concept of habitat condition is being applied as an indicator of environmental deterioration.

3. The report presents unrealistic expectations concerning information that can be provided through the current monitoring strategy with respect to determination of causality for observed trends and evaluation of the effectiveness of EPA's regulatory programs.

4. We strongly recommend that the EMAP team make maximum use of historical data and data from other sources to help guide design

of the monitoring program and complement EMAP monitoring data, and that it synthesize such information to provide timely assessments.

5. There is a need for better coordination and integration of indicator selection among the ecosystem classes, and between EMAP and the Ecorisk program.

6. We recommend that EMAP consider a pilot to test use of biogeographic regions as an assessment units as a possible alternative to assessment organized by ecosystem classes.

7. We recommend that EPA undertake an accelerated research program to develop improved ecological indicators that will identify changes in the ecosystem with sufficient sensitivity to be useful in assessing the state of environmental quality.

8. Subsequent versions of the Ecological Indicator Report should be revised to:

- Provide more explicit documentation of rationale for indicator selection and the process used.
- Discuss the classification of ecosystem types within each ecosystem class.
- Provide a glossary, and ensure consistent use of terminology.
- Include matrices of selection criteria for indicators.
- Clarify that EMAP is not designed to demonstrate causality.

Because the indicator concept is central to success of the EMAP program, and because the concept is still evolving and undergoing testing in pilot projects, we recommend that SAB revisit the indicators issue later in 1990 or early in 1991.

2.0 INTRODUCTION

The Environmental Monitoring Subcommittee of the Ecological Processes and Effects Committee of the Science Advisory Board met on May 8-9, 1990, to review the draft document "Ecological Indicator Report for the Environmental Monitoring and Assessment Program" that was prepared by the Office of Research and Development (ORD) of EPA. In addition to the draft report, the Subcommittee received a series of briefings concerning development of indicators from key EMAP participants.

The goal of the Environmental Monitoring and Assessment

Program (EMAP) is to provide unbiased estimates concerning the current and changing condition of ecological resources at regional and national scales. The EPA, U.S. Congress, and private environmental organizations have long recognized the need to improve our ability to document the condition of our environment. In 1988, the EPA Science Advisory Board recommended that EPA initiate a program that would monitor ecological resource status and trends, as well as develop innovative methods for anticipating emerging problems before they reach crisis proportions. EMAP is being initiated in 1990 by EPA in response to these needs.

A critical step within the program is the selection of indicators that effectively define the status and condition of ecosystems. The Indicator Report serves as an interim conceptual plan for the indicator component of EMAP until more detailed plans can be prepared for each ecosystem. The purpose of this document is as follows:

-- To inform potential EMAP data users of the approach proposed to describe ecological condition.

-- To outline a framework for selecting and evaluating indicators for further testing;

-- To seek expert advice and ecological data sets that might aid in these evaluations.

2.1 Charge to the Subcommittee

At the December 12, 1989, meeting of the Ecological Processes and Effects Committee, the Director of the Office of Modeling, Monitoring Systems, and Quality Assurance of ORD invited the Science Advisory Board to review critical aspects of EMAP. The Committee accepted the invitation and requested that ORD submit the draft document for Ecological Indicators to the Science Advisory Board for review. On March 28, 1990, ORD provided the draft report to the SAB for review. The Office of Research and Development asked that the Committee address the following questions as part of their review:

a. Are the concepts of the indicators clearly articulated?

b. Are the data in the appendices on individual indicators relevant and accurate?

c. Is the suite of indicators sufficient and appropriate for each ecosystem? Will the results of such monitoring be relevant given the temporal and spatial scale of the program?

d. Is the current classification of ecosystems appropriate?

3.0 EVALUATION OF THE INDICATOR REPORT

In evaluating the proposed approach to indicators, the Subcommittee found it necessary to consider the broader context of the EMAP framework. The selection of appropriate indicators is inextricably linked to EMAP's fundamental conceptual design and sampling strategy, as outlined in the initial sections of the Ecological Indicator Report.

Therefore, our comments address the general EMAP approach as well as the specific issue of indicators. To a large extent, these general comments reiterate or expand upon the Ecological Processes and Effects Committee's report on Evaluation of the Core Research Program for Ecology, transmitted to EPA on July 11, 1990.

Section 3.1 presents the Subcommittee's most significant findings.

Section 3.2 presents more specific comments with respect to indicators for the various ecosystem classes. Because of the breadth of subject matter and relatively limited time for review, the Subcommittee focused most of its attention to the issues reflected in 3.1, which we considered to be of a strategic nature. Our comments in Section 3.2 should be considered more supplementary in nature; they do not represent a definitive review of each of the ecosystem classes.

Section 3.3 presents recommendations concerning more effective presentation of information in subsequent versions of the Ecological Indicator Report.

3.1 General Comments

3.1.1 The EMAP Concept. The Subcommittee reiterates support for the EMAP concept. The EMAP strategy is to impose a grid on the U.S. and examine remote sensed (satellite and aerial photo) information in every grid cell to obtain a probability sample of landscape characteristics. This information will then be used to define strata and select sites for later sampling of chemical and biological variables on ground visits. In concept this strategy can offer a good combination of statistical sophistication, efficiency, flexibility, and practicability. Through its landscape characterization component, EMAP can be an important step toward establishing an integrated natural resources inventory for the nation and we believe this aspect of the program should be emphasized.

However, the Subcommittee has not reviewed statistical design of the program. At this stage, we have only been presented with a strategy. We do not yet know:

-- what variables will be measured?

-- what resolution is required?

-- what measurement technology will be employed?

-- how many observations will be made per stratum?

-- what is the natural variation in these variables?

In concept, when these are known, the evaluation of the statistical design will rest essentially on estimation of whether the proposed design (as specified in terms of measurement technology, number of observations) is in fact expected to deliver the required resolution (in light of the measurement error, sampling error, background variation).

Current understandings of natural spatial and temporal variability are probably inadequate to fully support such an evaluation; although this will vary among ecosystem classes and biogeographic provinces. This highlights the need for the EMAP planners to evaluate existing data sets and information on ecosystem variability in assessing the adequacy of the sampling design. We are concerned whether 800 sites per ecosystem class will be adequate to characterize variability over a large spatial scale or will only yield largely site-specific results. We are also concerned whether, without further stratification, the grid will give sufficient coverage to characterize conditions in smaller, but ecologically significant, ecosystems. We believe that the alternate approach of developing a stratified sampling plan based on existing knowledge ecosystems should be fully evaluated. Area sampling techniques may be required.

3.1.2 The EMAP Strategy. The Subcommittee supports the EMAP strategy of conducting pilot studies and stresses the importance of conducting and carefully evaluating the results of pilot studies to test EMAP concepts. Because of many unresolved questions, which will be outlined below, we wish to emphasize the importance of conducting and fully evaluating the results of initial pilot studies before beginning full-scale implementation of the monitoring program.

3.1.3 Interagency Coordination. The Subcommittee reiterates the Ecological Processes and Effects Committee's recognition of the importance of inter-agency coordination. We commend efforts to achieve interagency cooperation and participation in EMAP, and wish to emphasize the importance of continuing these efforts if EMAP is to succeed. Integration of monitoring efforts of other Federal agencies into EMAP, along with associated cost sharing, is both efficient and essential. In the case of forests, for example, compatibility with the U.S. Forest Service's Forest Inventory and Analysis program is very valuable and Forest

Service representatives should be active participants in the planning and implementation of the forest pilot studies.

At the same time, we recognize the potential risks in dependency of EMAP on other agencies such as the U.S. Forest Service, Soil Conservation Service, Geological Survey, Fish and Wildlife Service, and NOAA to produce much of the status and trends monitoring data. Therefore, formal arrangements between EPA and other agencies must be developed and commitments made to their scope and time commitments in regard to reporting results if complete and timely state-of-the-environment reports are to be published.

3.1.4 Peer Review. The Subcommittee feels that peer review is essential for all aspects of EMAP and commends the EMAP team for the level of peer review that has been incorporated into the development of the program. It encourages the continued use of appropriate peer reviews as components of the program are developed, refined, and implemented. In future reviews of EMAP, the SAB will focus on critical components (e.g., strategic plans, landscape characterization, demonstration projects, and risk characterization) and issues related to the relationship of EMAP to other EPA programs and objectives.

3.1.5 Discussion of the Charge. The Subcommittee addressed the four questions posed by ORD in its charge to us and we have specific concerns related to each, both with underlying content and with the manner of report presentation. The "Ecological Indicator Report for the Environmental Monitoring and Assessment Program" may be the first formal output of EMAP. EMAP is a major component of the Agency's core ecological research program and it will be the largest funded portion of that research effort. Since EMAP is based on monitoring, which of itself has always been controversial in the research community, its methods, approaches, and techniques will be scrutinized closely by the scientific community. This selection of ecological indicators and the rationale for sampling, is not only fundamental to the entire program but also may be an effort by which the entire program is initially judged a priori.

We recognize the inherent difficulties involved in identifying indicators for EMAP, and appreciate the substantial effort and progress reflected in the report. We further recognize that the report is being issued as an interim document and that many of the conceptual and substantive issues that we will pose below may not be quickly resolved, but we urge that they receive continuing attention as the program evolves. We also recommend an accelerated research effort to develop improved ecological indicators that will identify changes in the ecosystem with sufficient sensitivity to be useful in assessing the state of environmental quality.

3.1.6 Ecosystem Assessment. Clarification is required on the concept of assessing ecosystems as "nominal" or "subnominal." The report describes the EMAP assessment goals for determining the percentage of each ecosystem class that is in nominal versus subnominal condition nationally. However, the concept of defining nominal conditions has not been clearly developed.

A core difficulty seems to be a desire that the EMAP survey deliver an overall assessment of "ecosystem status" as a measure of ecological "health" or "integrity." This goal then motivated generation of a long list of indicators in the hope that these would somehow add up to an adequate measure of ecosystem status. However, there is no monolithic ranking of ecosystem status which captures whether the state of the ecosystem is good ("nominal") or not. A piece of landscape can be in good condition in one respect, and bad in another; it can be good for some uses, and bad for others.

Even where the reference site concept is used to describe "nominal" conditions, we must recognize that ecosystems are dynamic and are influenced by short and long-term natural forcing functions. Thus, the characteristics of an ecosystem may be fluctuating in ways that confound defining "nominal," unless response to natural variation can be incorporated in that definition. Since terrestrial ecosystems will be identified with vegetative type, the state of succession will be a factor. If by "nominal" we mean the potential ecosystem or the seer leading to it, then it will be necessary to identify the state of succession at the time of the assessment. In addition, it will be necessary to predict how an unperturbed site would change with time.

EMAP does not yet appear to have adequately addressed the question of change induced by natural stress. A major issue generic to all the ecosystem classes is the need to understand natural cycles which would affect the proposed indicators, as distinct from anthropogenic stress. For example, in the case of coastal systems, these would include diseases that result in mortality or death of bivalves and submerged vegetation, and cycles of fish population changes. The need to understand natural variability emphasizes the importance of utilizing historical data sets, where these are available, to help interpret data collected by EMAP.

One possible approach might be for the EMAP planners to abandon the concept of ranking ecosystems as nominal or subnominal. Instead, the focus could be on generating a short list of assessment endpoints which individually are directly justifiable in terms of societal/management interest, to adopt measurement endpoints that can be measured and related in some meaningful way to the assessment endpoints, and to rank the condition of ecosystems in those terms.

3.1.7 Habitat Indicators. Clarification is required on the definition of habitat indicators. Quantitative habitat loss is one measure of environmental deterioration that can be described clearly, but loss of habitat quality is less clearly defined. There is some ambiguity in the way the concept of habitat condition is being applied as an indicator of environmental deterioration. Ecosystem characteristics which describe the "natural" structure and function of ecosystems and which can serve to characterize ecosystems do not appear to be distinguished from those which are measures of physical deterioration (e.g., indices of range condition).

3.1.8 Sampling Strategy. The draft Indicators Report presents unrealistic expectations concerning the information that can be provided through the current monitoring strategy. The fundamental EMAP concept proposes annual monitoring at a statistically designed pattern of fixed stations. Adherence to the pre-determined sampling design will limit the selection of indicators and some otherwise relevant information will not be included.

An example is use of information on fisheries in the coastal demonstration; the Subcommittee agrees that it is not feasible to collect meaningful data on commercial fish populations in the EMAP sampling pattern. However, some mechanism for addressing the status of fisheries is essential to assess the condition of the marine environment in terms that will be most meaningful to policy makers and the general Public.

The Subcommittee has not reviewed the Near-Coastal Program Plan for 1990, but as we understand it, the pilot will not include assessment endpoints of general societal concern, such as status of fish populations, shellfish bed closures, recreational water quality, sea bird and coastal wading bird populations. Further, it will be inherently difficult, if not impossible, to link the proposed measurement indicators directly to such endpoints in any quantitative way. For example, the confounding effects of exploitation, such as sport and commercial fishing, will limit our ability to relate trends in marine environmental deterioration to changes in fish populations.

We understand the difficulty of including such assessment endpoints within the basic EMAP sampling design. At the same time, however, these are the questions that will be asked by the public and policy makers. This dilemma suggests two possible alternatives relating to the fundamental EMAP strategy:

a. Make a strong effort to supplement the EMAP field sampling of the limited suite of measurement indicators with relevant information collected from other sources and a broader base to provide interpretative reports on the condition of near-coastal resources. Examples are: NMFS and State fisheries catch

statistics; Fish and Wildlife Service information on breeding shorebird and waterfowl populations and on contaminants in colonial nesting wading birds. Information from such sources can help EMAP to interpret natural variation and population cycles in relation to various measurement indicators and assessment endpoints (e.g., declines in oysters and sea grass in the Virginian Province of the pilot study, which take place periodically due to disease outbreaks), or

b. Be more explicit that the EMAP coastal monitoring program is simply measuring some sentinels of marine environmental condition, and will not provide information that directly correlates with the status of endpoints of management concern. It could be extremely useful to meet this more limited monitoring objective, which can alert decisionmakers to trends in environmental deterioration and indicate the need for intensive field studies and research to determine the causes and societal consequences.

However, currently there is inconsistency between what the report indicates that EMAP will provide, and what the coastal pilot as proposed will actually provide. For example, the draft indicator report seems to imply that the monitoring program will explain causal relationships in many cases, and that it can be used to evaluate the effectiveness of EPA's regulatory programs. This could lead to false expectations and a loss of credibility.

3.1.9 Historical Data. The Subcommittee reiterates the Ecological Processes and Effects Committee's finding concerning use of existing data and recommends that the EMAP team make the maximum use of historical data and data from other sources to complement data from EMAP monitoring, and that it synthesize such information to provide assessments in a timely fashion. EMAP provides for incorporation of data from other monitoring networks and sources. However, it appears that EMAP may not be providing adequate resources or priority to analysis and use of historical data in interpreting the status and trends of ecological resources. Some provision is being made for use of "found" data, but this effort seems to be receiving only secondary attention in EMAP planning. The Subcommittee wishes to stress the importance of making adequate provision both in time and resources for incorporating, interpreting, and synthesizing all relevant information, including historical data (e.g., water quality monitoring, forest resource inventories, and agricultural resources).

No matter how well EMAP is designed, as we discussed above with coastal ecosystems, EPA's ability to interpret the findings of a fixed point sampling program with a relatively limited number of sampling points will be greatly enhanced if EMAP data are viewed in the light of other existing information. Perhaps even more important, analysis of existing knowledge may lead to

important modification in the EMAP program design. Such information may point to the need for adopting stratified sampling approaches or selecting other indicators without biasing statistical integrity.

Further, an emphasis on integration and synthesis will enable the program to begin to issue useful interpretative reports and findings early on. This will help assure continued interest and support for the major budgetary expenditures necessary to implement and maintain EMAP; it may not be possible to sustain the necessary commitment if many years elapse before some findings are issued.

3.1.10 Model Ecosystem Approach. The Subcommittee supports the approach described by the arid lands group. In relation to the above recommendation, the Subcommittee was impressed by the presentation made for the arid lands group, even though it was informal and preliminary in nature. Information available from other agencies, e.g., the Bureau of Land Management and the Soil Conservation Service, was used to prepare interpretative maps of arid lands for various parameters such as greenness and evapotranspiration. The approach of using remote sensing data seemed best developed in the arid land study. The indicators proposed seem well suited for a broad-scale study like EMAP.

We recommend that the other ecosystem groups examine and apply the approach used by the arid lands group. For example, the utility of the satellite mapping and aerial photography needs to be more clearly stated in each ecosystem. The present general plan is to use these tools for establishing the extent and boundary patterns of various resources. In the specific case of the arid ecosystems, it also planned to use information derived from remote sensing to estimate environmental impacts associated with such factors as grazing and decertification. The potential for broader use of remote sensing information should also be explored for other ecosystems classes.

3.1.11 Coordination and Integration. There is a need for better coordination and integration of indicator selection among the ecosystem classes, and between EMAP and the Ecorisk program. We observed inconsistency in the use of indicator terminology and concepts among the ecosystem groups, particularly in the oral presentations made to the Subcommittee. Criteria for choice of indicators also seemed to be unclear or specified unevenly applied among the various ecosystem groups. Further, although the report identified a number of cross-cutting indicators relevant to a number of ecosystem classes (Chapter 9), there was little indication that these would be incorporated as appropriate into the individual ecosystem classes.

In addition, we believe that there is a need for the EMAP program and the Ecorisk program, both are components of EPA's

Core Research program, to coordinate with respect to selection of endpoints and techniques for risk characterization. As the Ecological Processes and Effects Committee pointed out in its evaluation of the core research program, it is important to have a strong linkage and feedback between the field monitoring and risk characterization research. Monitoring can frame and define some research topics and research can focus monitoring procedures. We saw little evidence of such coordination.

3.1.12 Biogeographic Regions. The Subcommittee recommends that EMAP consider use of biogeographic regions as assessment units as a possible alternative to ecosystem classes. Development of EMAP around the concept of ecosystem classes (e.g., wetlands, forests, inland waters, etc.) poses some inherent problems:

a. Many "real-life" ecosystems include elements of more than one ecosystem category. For example, a watershed may include inland waters (rivers and lakes), various wetland types, agro-ecosystems, and forested areas. To characterize that system and understand ecosystem functions, interactions among the various elements must be understood.

b. In many cases, there is greater commonality among the elements within an ecoregion or biogeographic province than there is among different types within the same ecosystem category. For example, Spartina marshes relate much more closely to their adjacent estuarine waters than they do to mangrove swamps or bogs even though these are all categorized as "wetlands ecosystems."

The wetlands category of classification covers a particularly broad range of systems, including such disparate wetlands as salt marshes, northern cedar swamps, peat bogs, and southern cypress swamps. Their commonality is limited to the presence of water and the presence of plants that are adapted to water saturated soils. As a consequence of this very broad definition, ecosystems with only remote affinities are aggregated. Consequently, the actual ecological affiliations between a northern cedar swamp and a New Jersey salt marsh are probably less than the affiliations between a Michigan pine forest and a Kansas prairie. The individual members in the present category of wetlands clearly have their closest affinities to the adjacent upland ecosystems on the one hand, and the adjacent aquatic ecosystems on the other hand. Consequently, it is particularly important that the wetlands category should take cognizance of the relationships of the individual wetland ecosystems to their affiliated ecosystems.

c. Some ecosystems may have dual classifications because of affinities to more than one category. For instance, tundra may be classified as arid on the basis of low rainfall, but as wetlands on the basis of the occurrence of standing water, the

presence of plants adapted to water saturated soils, and the utilization as breeding territories by water birds. The extensive areas devoted to aquaculture in Arkansas and Mississippi can be classified in the category of agro-ecosystems or in the category of inland surface waters. The northern cedar swamps or the southern cypress swamps can be categorized as wetlands or as forests.

d. EMAP is attempting to monitor and assess ecological functions on a grand scale. The ecosystem classes ignore areas that are geographically and ecologically related and in some cases interdependent. Their nature and potential condition may be linked to a common, widespread geological, meteorological, or hydrological phenomena which are easily revealed through mapping. In addition, with the ecosystem classes, fundamentally different approaches are being taken to define indicators for different ecosystem categories. As a result, it will be difficult to link and compare conditions among the various ecosystem categories even where they occur in the same biogeographic region.

Therefore, we recommend that a pilot be developed for at least one inland area, selected from Omernik's ecoregions or other similar ecological classification system, in which an integrated EMAP approach be developed and tested. Based on the outcome of this pilot, a determination should be made concerning whether to move to an ecoregion approach instead of the current ecosystem categories approach as the basis for further program development.

3.1.13 Cost Estimates. The cost estimates in the report are questionable. The sampling and analytical costs presented in each of the appendices are open to question and criticism. They are difficult to evaluate in the context in which they are presented. Moreover, they are misleading because no summarization of total costs is provided for each ecosystem type. The numbers shown are without meaning because the component institutional costs, direct and indirect, are not reflected. Without these, one cannot arrive at an overall realistic estimate of the total program effort.

3.2 Specific Comments on Proposed Indicators

3.2.1 Cross-Cutting Indicators. The Subcommittee has additional specific comments as follows:

a. Biomarkers. The biomarker section in Section 9 of the report is generally well written. However, biomarkers also should be included more specifically within the individual ecosystem class discussions. In particular, the needs or uses of biomarkers in each ecosystem class should be specified.

The list on page 9-16 should distinguish changes in gene expression (i.e., synthesis of proteins in response to stressors)

from changes in enzyme activity/protein function.

The use of wildlife biomarkers to signal significant changes in the health of the ecosystem (or region) under consideration could be very valuable. There is, however, a spatial (and temporal) resolution issue that has not been clearly addressed. Different species (e.g., honey bees, frogs, birds) sample very different spatial scales and temporal scales. Therefore, biomarkers associated with animal species will have to be selected and monitored with knowledge of the temporal variations in species behavior (e.g., change in location as a function of the season). For example, for migratory species (e.g., birds), effects as revealed by biomarkers evaluated for a given species in a given site and a given time could be the consequence of events of prior time. Thus, the time-effects correlations may, in some cases, be extremely difficult due to the coupling of spatial and temporal features associated with specific indicators and regions.

An alternate approach to use of species-specific biomarkers might be to identify biological guilds and monitor the rate of resource utilization, as has been done successfully for aquatic systems by Cummins et al (1989. Shredders and Riparian Vegetation. Bioscience 39:24-30).

b. Regulatory criteria or standards, such as closing of shellfish beds and beaches due to fecal contamination, or health advisories on fish consumption due to chemical contamination, are important indices by which environmental decisionmakers and the public assess the status of the environment. These regulatory requirements are not uniformly stated (e.g., individual States have different criteria for advisories, fishing bans, and closures). Further compliance or non-compliance may be unrelated to environmental contamination or effects that can be monitored directly. Despite these limitations, compliance with environmental criteria represents an important way of describing environmental status and trends. Therefore, EMAP should consider how to incorporate information on such compliance in its assessments.

c. Sediment/soils represent sinks of contaminants for all of the ecosystems evaluated by EMAP. These data can thus provide an important link between ecosystems. The collection of sediment/soil contamination data should be incorporated as an exposure indicator in all of the ecosystem types and the methodologies standardized to facilitate comparisons between ecosystems.

d. Climate and atmospheric deposition are driving variables that are the root of much ecosystem variation and should be measured along with the ecosystem indicators. The coupling of atmospheric deposition monitoring with ecosystem

monitoring is essential. Over time, it will permit correlation studies of the relationships between air quality and ecosystem responses. These correlations may prove very valuable in efforts to partition stress effects between natural and anthropogenic stress factors.

Atmospheric deposition is the source of a significant portion of toxicants coming onto a site whether terrestrial or aquatic. In addition to efforts to calculate deposition loadings at reference sites for all regions, there should be an effort to tie deposition to sources by considering meteorological patterns.

3.2.2 Wetlands. The Subcommittee had some specific comments on the wetlands chapter as follows:

a. This chapter is generally well done. The choice of response indicators appears appropriate but the exclusion of primary production as a response indicator should be discussed further by the team.

b. Unlike the other ecosystem discussions, the developmental indicators are only presented in the table in 5-7 but not discussed in the text. The relevance of these developmental indicators in evaluating wetlands should be reviewed at least briefly.

c. There is a major problem with the lack of connection between the various types of wetlands and the ecosystems to which they are physically linked. An example is the salt marsh-wetland ecosystem and its linkages to the adjacent estuary. As we have previously indicated, these issues should be discussed and the various types of indicators should be compatible so that the data can be compared and the linkages evaluated.

d. Chemical concentrations in the sediments are called for in Figure 5-1 and on page 5-10 and, as already indicated, these are important contaminant sinks. However, there is some question about the validity of such measurements within the limited sampling periods proposed by EMAP. Chemical activity in wetlands sediments is extremely complex. What one finds one day can be quite different the next. Since wetlands are shallow water systems, the sediment quality is subject to changes related to atmospheric conditions. High evaporative and transportational losses will modify both ionic and cationic migration as will sudden dilution of the surface water with precipitation. Therefore, these short-term variations could mask significant trends unless provision is made for more intensive sampling.

In any case, sediment monitoring should be linked to ongoing work in the agency on sediment quality criteria (i.e., AET and EqP methods) so that the data can be integrated into these programs and to facilitate its interpretation.

e. Some wetlands are on a relatively short successional timeline (i.e., acid bogs). This further illustrates the issues discussed in 3.1.6, above, with respect to the need to differentiate between anthropogenic change and man-mediated changes, and problems associated with definition of "nominal."

3.2.3 Near-Coastal Waters. The Subcommittee comments on the Near-Coastal chapter do not reflect subsequent EMAP work done in preparing the Near-Coastal Program Plan for 1990, which we have not reviewed. We recognize that some of our comments may have been superceded by that document. Our comments on the Ecological Indicator draft are as follows:

a. Choice of assessment endpoints. The Near-Coastal program identified assessment endpoints related to the public's use of near-coastal ecosystems for commercial and/or recreational fishing. Primary endpoints are the health of fish and shellfish populations. A second major endpoint of concern is the maintenance of near-coastal habitat structure. Public perception of the aesthetic value of the resource is the third endpoint, with clarity of water as influenced by suspended solids and/or algae as the measurement endpoints for this area. The Subcommittee agrees that these three categories of endpoints relate to aspects that the public values and therefore are reasonable assessment endpoints toward which to direct a status and trends monitoring program.

b. Response indicators. The core response indicators proposed are dissolved oxygen and benthic abundance, biomass, and species composition. These indicators are related to the assessment endpoints, even though as previously indicated it will not be possible to establish quantitative relationships, and they seem to be reasonable choices.

c. Interpretation of benthic community data will be extremely difficult without information on the benthic habitat. The distribution of benthic organisms is highly dependent on the nature of the habitat. Some effort should be made to physically characterize the habitat present at the sampling sites with respect to both grain size and organic carbon content. Sediment grain size alone may not be adequate.

d. While the Subcommittee recognizes the difficulties in collecting fish, it recommends that fish abundance and species composition (NOTE: Contrast with acknowledged problem on fish population data under 3.1.8.), and fish gross pathology be considered within the program. These two measurements most directly relate to the public's assessment endpoints. We recognize that fish abundance is affected by natural cycles, fishing effort, and anthropogenic chemicals, and that it will be difficult to separate the influence of these different factors on

species abundance. We have discussed fundamental issues associated with inclusion of fish population sampling in our comment 3.1.8., above.

With respect to the gross pathology, the fish health protocol developed by R.W. Goude (Experimental Fisheries Research Laboratory, Division of Wildlife Resources, State of Utah, Logan, Utah) should be investigated for use in place of (or in addition to) the gross pathology indicator. This protocol has been tested on cold and warmwater, freshwater, and marine species with considerable effect. It requires little more effort than a gross pathology examination and will give an earlier warning signal than gross pathology. Fish abundance is affected by natural cycles, fishing effort and anthropogenic chemicals. It may be difficult to separate the influence of these different factors on a species abundance.

f. The report identifies several promising developmental endpoints. The Subcommittee agrees with the report that additional research is needed before biological mixing depth and presence of large infaunal bivalves can be routinely used. The report also indicates that extent and density of submerged aquatic vegetation cannot be routinely implemented, and proposes it as a developmental indicator. While it is possible to routinely sample for aquatic vegetation, it may not be suitable as an indicator within the EMAP sampling scheme since submerged vegetation is not present in many coastal areas of the southeastern United States.

This issue may apply to other indicators as well: dissolved oxygen sampling would not be useful in highly flushed areas where there are high daily tide changes, and water clarity studies would not be useful in naturally turbid. Areas of sewage outfalls often have large, healthy bivalves due to organic enrichment. This suggests that the suite of proposed indicators may be useful for some sites but not for others.

g. Shellfish growth was eliminated as an indicator (page 3-13) because changes in growth could not be related to specific environmental problems. This is not an appropriate reason for eliminating this endpoint. It is important to acknowledge that other response indicators, including benthic abundance suffer from the same lack of specificity.

h. An important biological process which was not covered by an indicator, except for some toxicity tests, was reproduction. A variety of events are important in reproductive success of vertebrates and invertebrates which have received intensive study. These include ovary formation, synthesis of vitellin (major egg protein), and hatching of young and the levels of fecundity and fitness. If normal reproduction is occurring in a species, it is probably one of the best indicators

that the species will maintain its population. Indicators based on reproduction should be considered for inclusion in the program.

i. **Exposure indicators.** Core exposure indicators include acute sediment toxicity, chemical contaminants in sediments, and water clarity. The Subcommittee is concerned that a suite of acute sediment toxicity tests are not proposed; use of a single amphipod species for evaluating sediment toxicity is inappropriate. Experience gained from ambient toxicity testing in freshwater and marine ecosystems has demonstrated that it is prudent to use a battery of assay organisms to determine water and sediment toxicity because of the range of sensitivities of assay organisms to toxicants. Lacking knowledge on the toxicant(s) present in coastal waters and sediments, it seems wise to include a battery of assays. Further, EPA's guidelines for establishment of water quality criteria call for bioassays on an array of organisms.

The report proposes that sediments be assayed for NOAA's list of proposed measurements in surficial sediments. While many of the chemicals on NOAA's list are important chemicals of concern, it might be advisable to use a broad screening approach such as that used in the Chesapeake Bay. This approach can incorporate specific chemicals of concern as well as provide information on a much wider range of contaminants.

It is unclear to the Subcommittee why the chemical residues in fish and shellfish were not included as a Core Indicator. Levels of contaminants in fish and shellfish directly relate to an assessment endpoint valued by the Public.

j. Use of EMAP indicators for "early warning." It is difficult to predict what future problems lie ahead for the coastal zone, but if the EMAP approach can provide an "early warning," it could prove very useful. One way of assessing the usefulness of the proposed indicators is to assess whether they would have been able to predict subsequent environmental problems in coastal waters, e.g., problems with PCBs, Kepone, and tributyl tin. Other than through some of the proposed chemical analysis, it is not clear that the indicators would have "caught" these problems. Many of the proposed indicators have been useful only where pollution is quite dramatic. These include gross fish pathology and most of the biomarkers. We have no specific recommendations concerning the "early warning" issue, but believe that it merits continuing attention by the EMAP planners.

3.2.4 Forests. We have the following comments with respect to the Forests strategy: The primary measurements most appropriate for forest monitoring include tree height and diameter, leaf area, and analyses of soil contaminants. From these, core indicators including growth efficiency, leaf area

index, and integrity of foliar can be calculated. These primary measurements are superior because they are simple, standardized, time-tested, and they integrate forest tree response with multiple stress factors. The technology for leaf area measurements is developing rapidly, and soon, it is highly probable that strategies for land-based, low altitude, and satellite measurements will be improved. Leaf area is the most useful leaf characteristic available. Foliar symptoms are not always specific to different stresses, but forest damage that has been induced by ozone and certain other gaseous pollutants can be identified with some degree of certainty. Other than these few instances where foliar symptoms can be identified, elaborate efforts to inventory various types of symptoms may not be cost effective. Leaf biomass is the critical factor that determines forest productivity.

The analysis of persistent contaminants (e.g., heavy metals and chlorinated organics) in forest soils (particularly those of the forest floor) is especially appropriate for a long-term infrequent sample cycle as proposed for EMAP. However, the variances associated with foliar and soil nutrient analyses may render these measurements of limited usefulness. Needles of conifers also offer a valuable method of measuring amounts of deposition over shorter time scales because there are usually several year classes of needles present, and the needle configuration is favorable for collecting gases and particles. Proposed pilot studies in the northeast and southeast represent an excellent opportunity to test or evaluate procedures.

3.2.5 Arid Lands. As already indicated, the Committee was impressed with the concept developed for arid lands and particularly with the utilization of remote sensing techniques for eliciting many of the indicator variables.

a. EMAP issues are, to a large extent, resource issues that have application on a global scale. It is to the credit of the arid lands group that they are taking advantage of international experience in the formulation of their plan. Particularly useful will be the reference to the experience and data of the IBP and LTER efforts.

b. Much of the arid west is under little plant cover and is subjected to substantial fetches of wind reaches. These forces may be instrumental in redeposition of materials accumulated in friable playa soils. Consideration should be given to establishing meteorological sites to measure this deposition and its distribution patterns.

3.2.6 Agro-ecosystems. Our comments on agro-ecosystems are as follows:

a. The category of agro-ecosystems represents a somewhat

artificial aggregation of systems from an ecological point of view. The commonalities between rangelands, row crops, orchards, and aqua-culture appear to be remote, and it may be advisable to assign some of these agro-ecosystems to ecosystem categories with which they may have closer affinities, such as rangelands with prairies and aqua-culture with aquatic systems. Alternative, a clearly established mechanism to foster integrated assessments among categories of ecosystems is required. (See comment 3.1.12, above).

b. Agriculture in the arid regions of the country poses fundamentally different problems for the environment than agriculture in those regions of the country where water is not a major limiting resource. Consequences of irrigation practices, such as increased rates of salinization and the transport and accumulation of elements that result in toxicity, such as selenium and boron, are examples of the overlap and special coordination that is needed between the groups dealing with agro-ecosystems and arid land ecosystems.

c. It is important that the assessment of agro-ecosystems take account of social-political actions to be able to assess changes in farming activities due to actions such as incentives to let land lie fallow (e.g., the Soil Bank), trends toward low-tillage agriculture, "clean" versus "dirty" farming, etc.

3.3 Recommendations for Revising the Indicator Report.

The Subcommittee has several recommendations toward a more effective presentation of information in the report in addition to more substantive comments on selection and testing of indicators. These comments were conveyed orally to EPA representatives after our May 8-9, 1990 review, and we understand that they were considered in revising the draft report. If not, we recommend that they be reflected in any future reports on this topic.

3.3.1 Document Rationale. The sections dealing with indicator strategies for particular ecosystem types suffer from insufficient description and rationale. The audience that may be reading this report is likely to be a critical one, and a scientific case has to be made for each suggested indicator or developmental indicator for each ecosystem type regardless of length. This may involve including more information from the appendices in the body of the report.

3.3.2 Resource Types. Include information on resource types for each ecosystem. In the draft report, very little information is included in each ecosystem category chapter on the types of ecosystem within that category. However, it became evident during the briefing that the classification of ecosystems within each category has a direct bearing on the choice of

response and exposure indicators. Each ecosystem category chapter should include a discussion of the classification approach used (e.g., biogeographic regions, biomes, domains, etc.) and the role this classification played in the selection of indicators. As it currently exists, the report is opaque in this regard and the reader is left to speculation.

3.3.3 Consistency of terms. The Subcommittee found the report to be generally consistent in its use of terminology. However, during the briefings, it was evident that different ecosystem teams had different definitions for concepts such as assessment endpoints, response indicators, etc. These definitions produced some confusion within and among team members and for the individuals being briefed. A well-defined glossary of terms should be included in the report which is used by all members of the EMAP team.

3.3.4 Indicator Selection Criteria. The Subcommittee recommends that each ecosystem chapter have a matrix added to it, which includes all candidate indicators considered for that ecosystem and all evaluation criteria applied by the team to screen candidate indicators. This would effectively communicate to a reader the universe of candidate indicators considered for each ecosystem and the rationale for identifying final core indicator candidates and the selection of developmental indicators. It would also assist in evaluating the consistency of selection criteria and indicators between ecosystems. The Forest Ecosystem team presented a very informative diagram in which they ordinated their candidate indicators by feasibility versus interpretability. The Subcommittee recommends that consideration be given to a similar presentation in each ecosystem chapter.

3.3.5 Causation versus correlation. The Subcommittee feels that the report should be carefully edited to clearly point out that EMAP is not designed to demonstrate causality. In several chapters, this point is not as strongly made as the Subcommittee feels it should be. For example, many of the figures, if examined out of context, imply that EMAP monitoring may demonstrate causality for subnominal conditions; whereas, in general, such monitoring can probably only demonstrate environmental trends.

3.3.6 Indicator Development Process. The Subcommittee recommends that the report include in each ecosystem chapter, a section which discusses how the team arrived at the final candidate indicators. Information should be presented on who was on the team, the role of outside reviews, name and affiliation of reviewers, etc. Inclusion of such information helps place the product of each chapter in perspective and makes the process transparent.

3.3.7 **Indicator Research.** It could be useful to include, perhaps as a separate appendix, a more penetrating explanation of important research topics related to ecological indicators. This could be valuable input for ORD to use in developing its core research program; as already indicated, we recommend an accelerated research effort in this area.

3.3.8 Summary chapter. The present Executive Summary needs work. In part, it seems to be a shortened and cut version of a number of the sections. The summary should cover the rationale, the bioindicators concepts, and an explanation of the differences between categories of indicators without lifting text material directly from the sections which is what the present summary reflects. Further, it is recommended that the summary chapter compare and contrast the assessment endpoints, response, exposure/ habitat, and stressor indicators by ecosystems. A summary matrix such as was presented by Dr. Hunsaker during the briefing could be used as the centerpiece of such a chapter. **The Subcommittee recommends that more effort be made to analyze, compare, and contrast the various paradigms directing the selection of indicators between the ecosystems, and that the results of this analysis be included in the summary chapter.**

4.0 SUMMARY OF RECOMMENDATIONS

The Subcommittee reiterates its support for the EMAP concept. We recognize that the Ecological Indicator Report is being issued as an interim document to summarize work to date and to elicit further comment, and we reviewed it as such. We have a number of fundamental questions with respect both to the selection of indicators for EMAP, and to the way in which information is presented in the report. Our findings and recommendations are:

1. Clarification is required on the concept of ranking systems as "nominal" or "subnominal"; this concept has not been clearly developed.

2. Clarification is required on the definition of "habitat" indicators. There is ambiguity in the way the concept of habitat condition is being applied as an indicator of environmental deterioration.

3. The report presents unrealistic expectations concerning information that can be provided through the current monitoring strategy with respect to determination of causality for observed trends and evaluation of the effectiveness of EPA's regulatory programs.

4. We strongly recommend that the EMAP team make maximum use of historical data and data from other sources to help guide design

of the monitoring program and complement EMAP monitoring data, and that it synthesize such information to provide timely assessments.

5. There is a need for better coordination and integration of indicator selection among the ecosystem classes, and between EMAP and the Ecorisk program. We saw little evidence of such coordination.

6. We recommend that EMAP consider a pilot to test use of biogeographic regions as assessment units as a possible alternative to ecosystem classes.

7. We recommend that EPA undertake an accelerated research program to develop improved ecological indicators that will identify changes in the ecosystem with sufficient sensitivity to be useful in assessing the state of environmental quality.

8. We have a number of specific comments and suggestions concerning indicators for the individual ecosystem classes.

9. Subsequent versions of the Ecological Indicators Report should be revised to:

- Provide more explicit documentation of rationale for indicator selection and the process used.
- Discuss the classification of ecosystem types within each ecosystem class.
- Provide a glossary, and ensure consistent use of terminology.
- Include matrices of selection criteria for indicators.
- Clarify that EMAP is not designed to demonstrate causality.

Because the indicator concept is central to success of the EMAP program, and because the concept is still evolving and undergoing testing in pilot projects, we recommend that SAB revisit the indicators issue later in 1990 or early in 1991.